FREQUENCY TRIPLER WITH INTEGRATED BACK-TO-BACK BARRIER-N-N$^+$ (bbBNN) VARACTOR DIODES IN A NOVEL SPLIT-WAVEGUIDE BLOCK AT 220 GHz

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ABSTRACT

A frequency tripler has been developed using an integrated planar back-to-back barrier-n-n$^+$ (bbBNN) varactor device in a waveguide mount at 220 GHz. The multiplier is based on a novel split-waveguide block design and a new fully integrated planar device architecture. Planar GaAs bbBNN devices have been combined with quartz microstrip filters in a wafer level circuit integration process. A tripling efficiency of 4%, the highest yet reported from a bbBNN structure at this frequency, has been obtained. Details of the block design, device fabrication process and measured performance are presented.

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Frequency multipliers using planar varactors rather than whisker contacted devices are being developed in order to meet the local oscillator requirements for future millimeter- and submillimeter-wave space applications [1,2]. Both novel varactor structures and circuit concepts are being investigated. The planar back-to-back barrier-n-n$^+$ (bbBNN) is one promising candidate varactor for space terahertz frequencies [2,3]. Its sharp, symmetric CV characteristics and low series resistance make it attractive for submillimeter wave applications [3,4].

Mounting discrete planar structures in high frequency multiplier circuits is often difficult due to the necessity of keeping the chip size much less than a wavelength. In order to avoid the problems associated with handling and mounting very small structures and open the door for very high frequency operation, bbBNN devices are being developed with integrated microstrip RF filter circuitry. To produce these integrated structures, a new fabrication process has been developed, in which most of the processing is done from the backside of the wafer. This is accomplished by laminating the device wafer, GaAs or InP, to a passive low-dielectric constant substrate, such as fused quartz, on which the microstrip circuitry will be formed. The process eliminates all non-essential high dielectric semiconductor material. The front of the wafer is exposed to a minimum of processing to protect the thin blocking layers on the front surface. Fig. 1 shows a bbBNN device integrated with an RF filter on quartz using this fabrication technique. Devices show symmetric CV characteristic with

C_{max}/C_{min} greater than 2 and IV characteristic with leakage current less than 1 μA and breakdown voltage greater than 9V. This fabrication process is not limited to the circuitry described here and has potential applications for other devices and circuit structures.

In order to provide appropriate embedding impedances to a varactor diode, multiplier mounts usually require complex waveguide structures with several tuning elements. A novel split-waveguide mount has been used to provide the proper embedding impedances to the integrated bbBNN varactor [5]. It consists of two block halves, which are mirror images of each other. The structure is well suited for planar diodes integrated with a microstrip RF filter and its fabrication is much easier than that of a traditional crossed waveguide mount, The compact design, with very short input and output waveguides, reduces waveguide losses. Both the input and output waveguides have two sliding backshorts, providing a series- and a parallel-tuning element at both frequencies. One half of the new mount, with the integrated bbBNN device is shown in Fig.2.

The tripler performance was measured using the test set up of [6]. An integrated bbBNN varactor with CV and IV characteristics of Fig.3a and 3b, is used to obtain the tripler performance of Fig.4. The efficiency of the tripler reaches its maximum value of 4% at 204 GHz with 5 mW input power. This is the highest efficiency yet obtained with a bbBNN device at this frequency. Additional work is ongoing and improvements in device power handling capacity and efficiency are expected.

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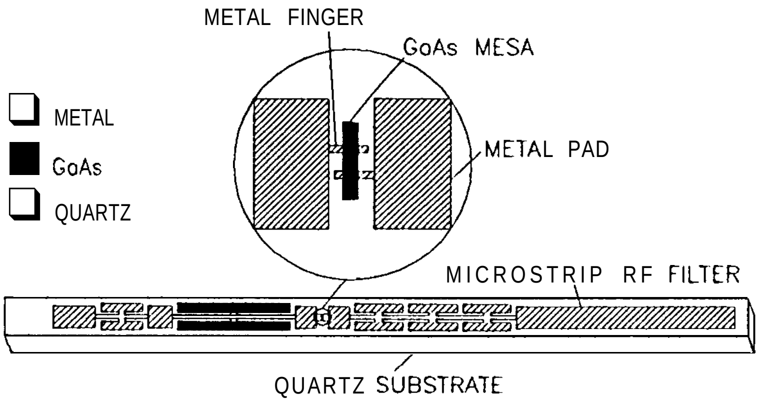

Fig.] Schematic diagram of an integrated planar bbBNN varactor structure

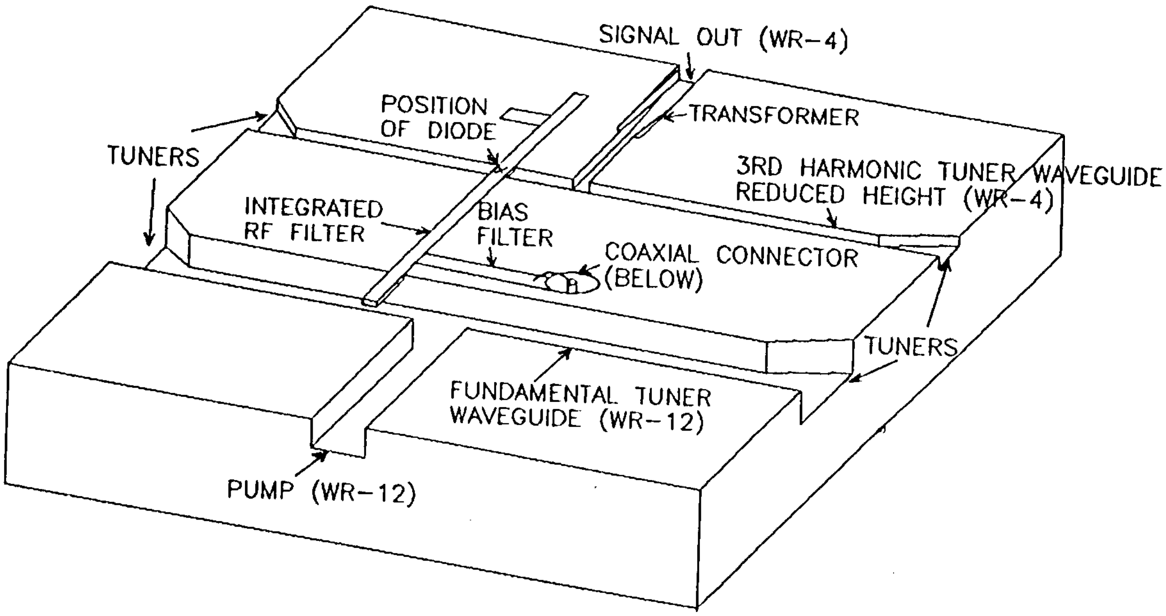

Fig.2 Schematic diagram of one half of the split-waveguide 220 GHz tripler mount with the integrated bbBNN device,

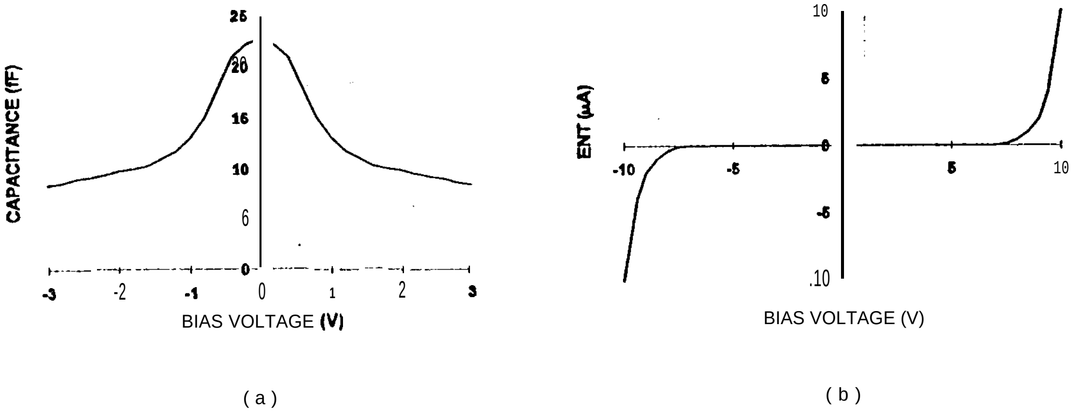

Fig.3 (a) Capacitance-voltage and (b) current-voltage characteristics of an integrated bbBNN diode.

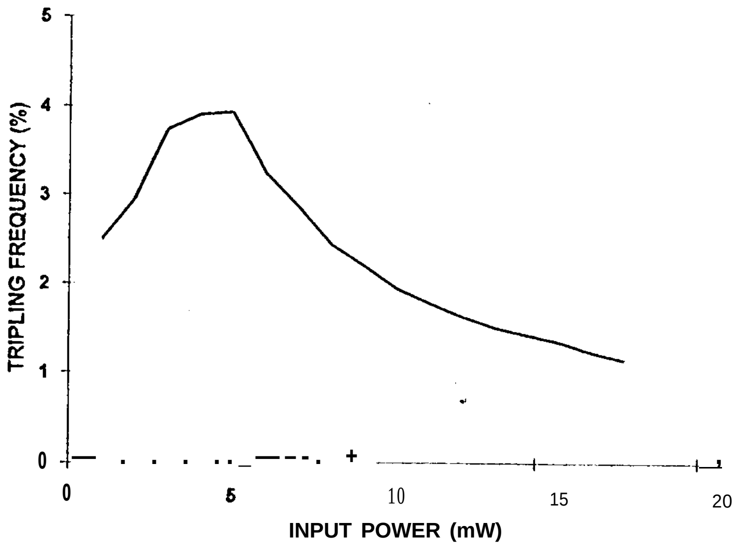

Fig.4 Measured tripling efficiency versus input power plot. Pump frequency is 68 GHz.